SysThink / SysSpeak
...Our Engineering Leadership Responsibility

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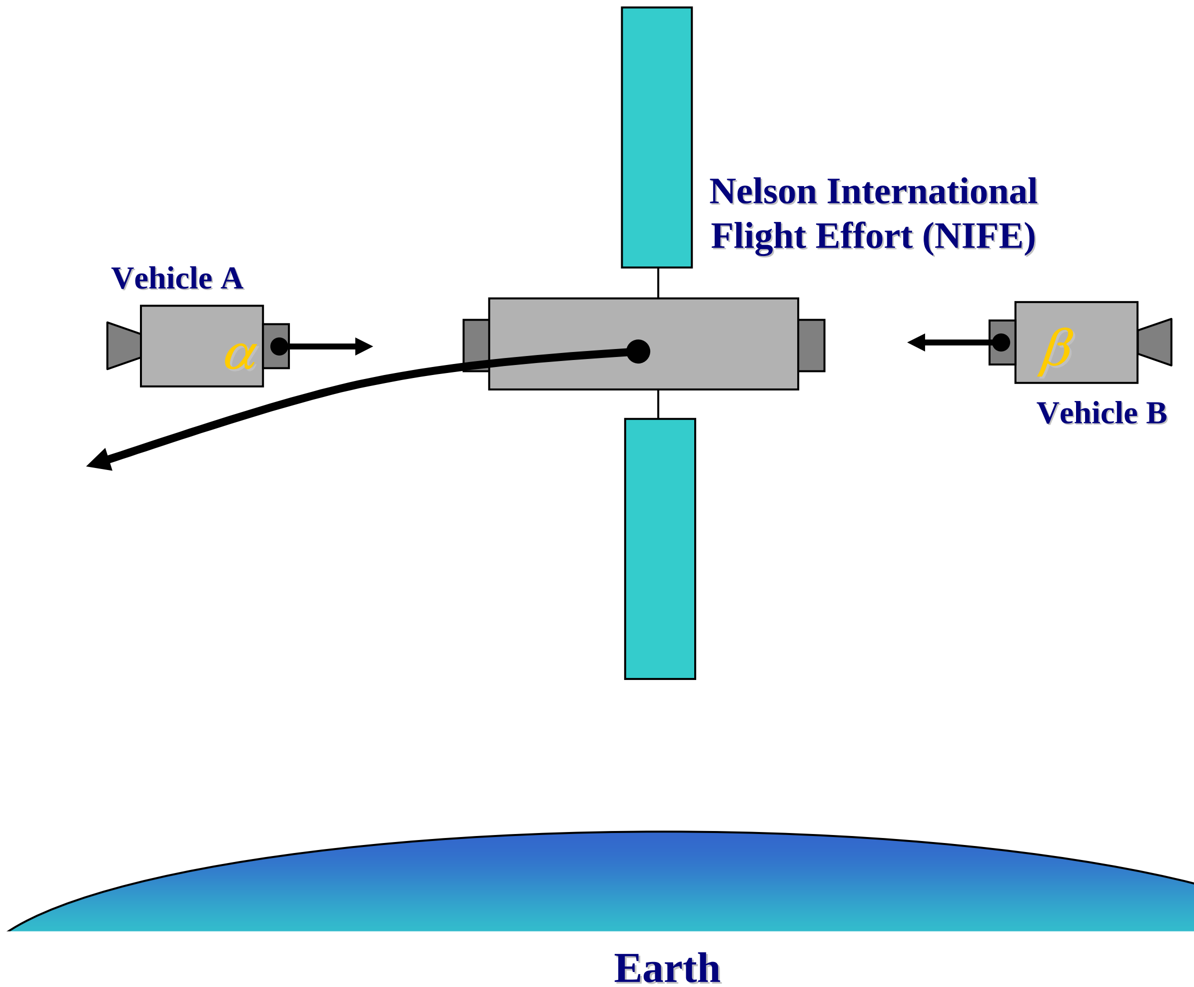
SysThink / SysSpeak

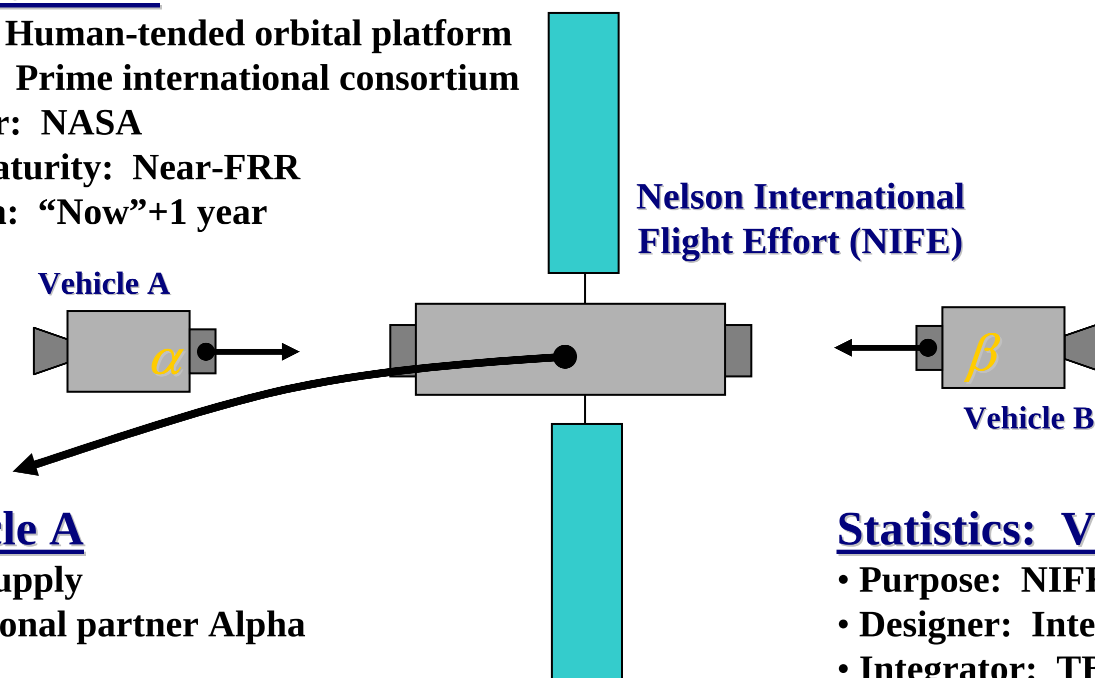
...our engineering leadership responsibility

Pop Quiz: What is wrong with this picture?



Pop Quiz: What is wrong with this picture?

…*how about now?*



Statistics: NIFE

- Purpose: Human-tended orbital platform
- Designer: Prime international consortium
- Integrator: NASA
- Design maturity: Near-FRR
- 1st launch: "Now"+1 year

Statistics: Vehicle A

- Purpose: NIFE resupply
- Designer: International partner Alpha
- Integrator: TBD
- Design maturity: Near-PDR
- 1st launch: "Now"+6 years

Statistics: Vehicle B

- Purpose: NIFE resupply
- Designer: International consortium Beta
- Integrator: TBD
- Design maturity: Near-PDR
- 1st launch: "Now"+5 years

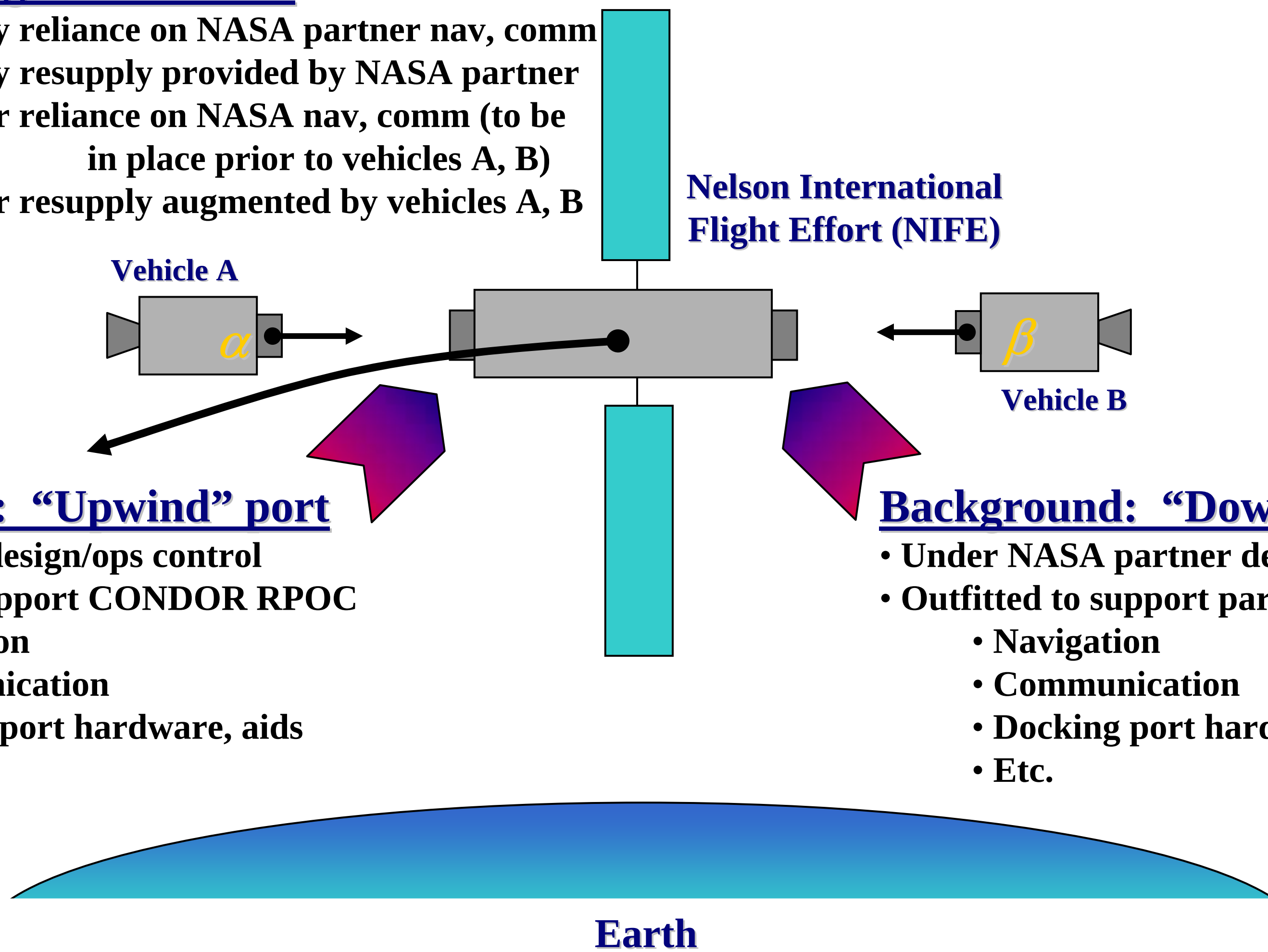
Earth

Pop Quiz: What is wrong with this picture?

…& *now*?

Background: NIFE

- Early reliance on NASA partner nav, comm
- Early resupply provided by NASA partner
- Later reliance on NASA nav, comm (to be in place prior to vehicles A, B)
- Later resupply augmented by vehicles A, B



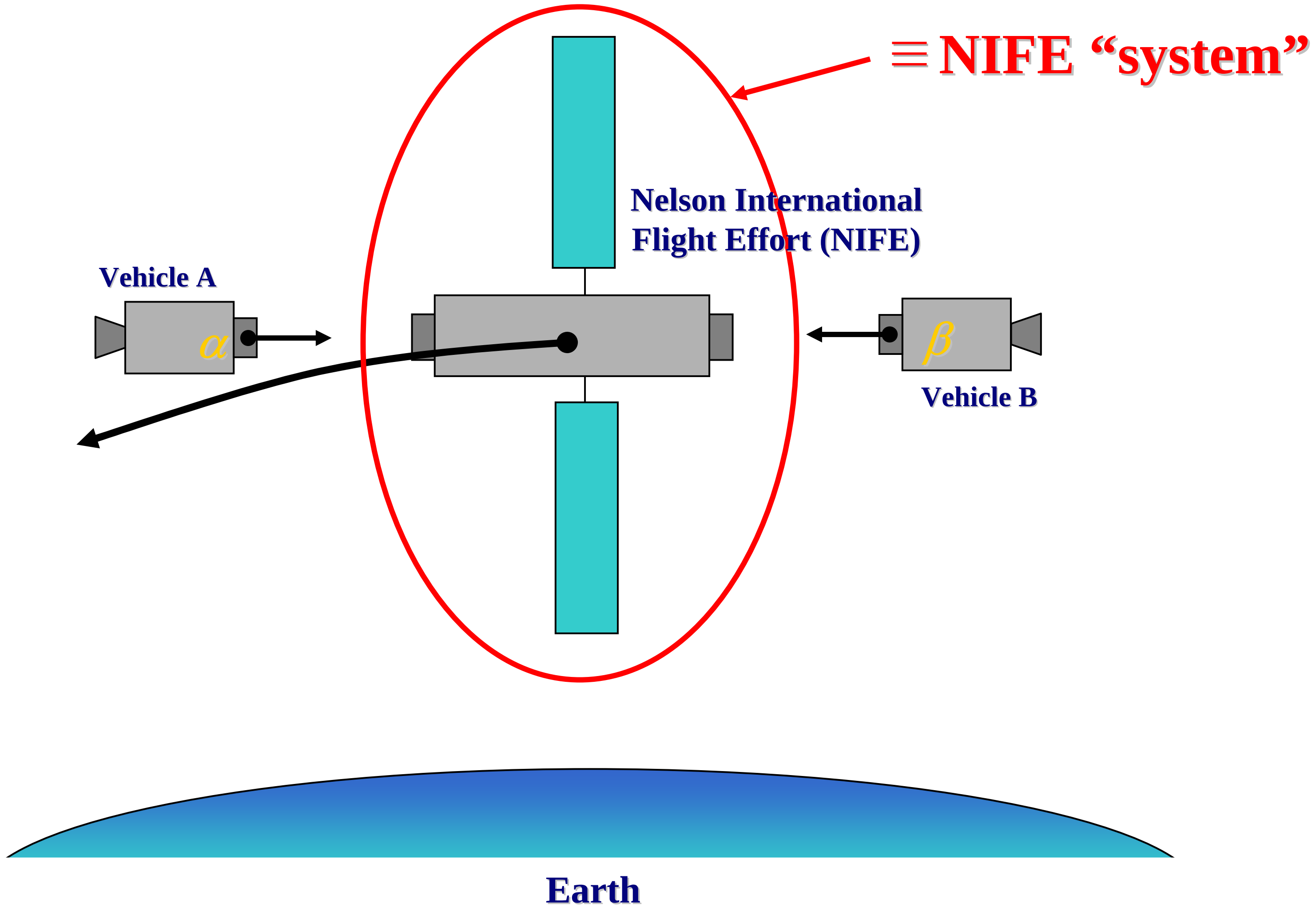
Background: "Upwind" port

- Under NASA design/ops control
- Outfitted to support CONDOR RPOC
  - Navigation
  - Communication
  - Docking port hardware, aids
  - Etc.

Background: "Downwind" port

- Under NASA partner design/ops control
- Outfitted to support partner vehicle RPOC
  - Navigation
  - Communication
  - Docking port hardware, aids
  - Etc.

The (simplistic) answer...



The problem(s)…

- **Inadequate definition of boundaries for NIFE "system"**
- **No up-front programmatic responsibility taken for integration**
- **Decisionmaking driven by political pressures to an extreme that allowed simpler (& there-fore cheaper, more time-effective & more *politically appealing*) solution to be overlooked**
- **Inadequate indoctrination of Systems Engineering/Integration principles into NIFE culture**

The impacts…

- **Short-term (false sense of) well-being**
- **Erosion of NASA reputation among international partners expecting agency to lead**
- **Long-term magnification of technical, cost & schedule problems through procrastination**

The lessons…

(…apologies in advance to Mr. Orwell!)

- **Need infusion of Systems Engineering/Integration into Program Office culture… aka:**

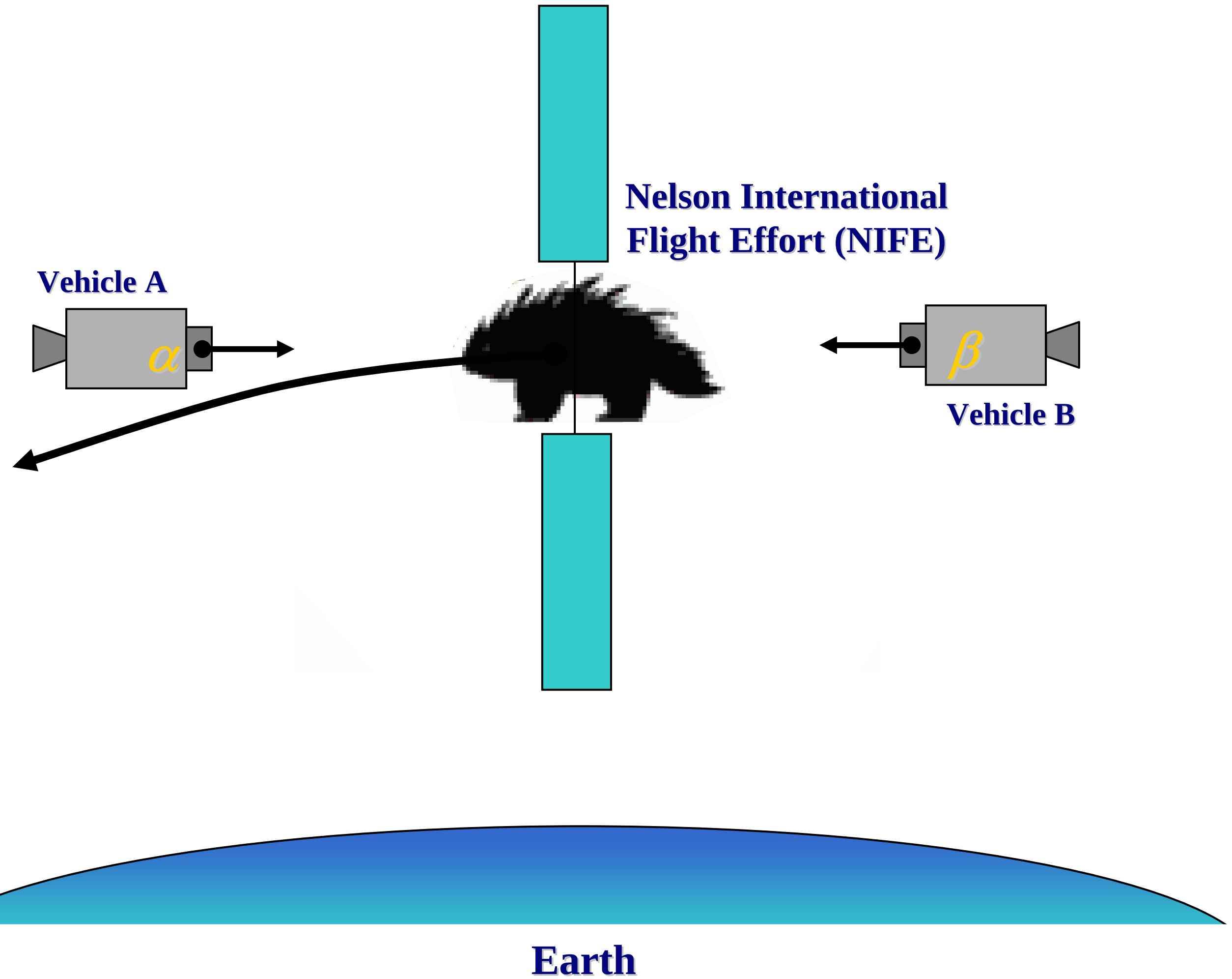
SysSpeak

- **Once knowledge is resident, must indoctrinate attitude to base decisions thereon… aka:**

SysThink

- **We all need to realize that SysThink & SysSpeak are professional/moral obligations!**

...and, so what did we do about this...??



Backup Material:

...“SysThink / SysSpeak”

"SysThink / SysSpeak" …by Michael C. Jansen

George Orwell's classic, *1984,* coined terms such as "newthink" and "Newspeak" to describe a mindset and the manner of its incorporation into the common language for the purpose of indoctrination. Although his connotation was negative, there is a positive element to be gleaned from the concept, and the completeness of its application to any given project often determines the degree of its success. That concept is the indoctrination, this time of a positive value, into the collective mindset of a project team. The positive value is systems engineering/integration; the mechanisms of its indoctrination could be termed "SysThink" and "SysSpeak."

What is wrong with the following picture? A major human-tended orbital platform is conceived and sold to the funding entity complete with resupply and emergency departure models that require the development of several new space vehicles. Under pressure to reduce the budget to make the program more salable, resources earmarked for the development of interfaces to these new vehicles are dropped as a "tomorrow problem." The international partners responsible for developing two of the vehicles request Program support and direction but receive none; their designs proceed in a vacuum.

Sound far-fetched? How about when you add the fact that neither vehicle supplier has previous experience in the design and operation of space vehicles, let alone ones that must rendezvous with another vehicle already in orbit? Plus that the rendezvous and capture is to be done autonomously by the incoming vehicle, something rarely attempted even by the two veteran spacefaring nations? And that resupply, the lifeblood of the orbital platform, depends in the out-years on the reliable availability of these new vehicles?

This was one of the interesting situations presented to me five years ago as I learned about my new job as my Division's Chief Engineer for the Nelson International Flight Effort (NIFE). The first obvious "broke" was that there was no single integrator; the second was that our Division's expertise in rendezvous, proximity operations, and capture (RPOC), going back to Apollo days, was not being applied to the problem. This, of course, stemmed in part from the NIFE Program's refusal (for budgetary as well as Civil Service personnel shortage reasons) to recognize the situation as being serious and in need of immediate attention. Once my RPOC team and I corrected this situation and caused responsibility for this technical area and coordination/integration of all international visiting vehicles to be conferred upon us by the NIFE Program (the topic of another story…), we were immediately faced with myriad other technical and political "brokes." While most of them were representative of the Program's inadequate early attention to systems engineering and integration in the RPOC arena, one particular example could have been its poster child.

First, some background… Vehicle A, a contribution of international partner Alpha, was planned to rendezvous with the "upwind" NIFE docking port; Vehicle B, to be supplied by international consortium Beta, was to dock with the "downwind" port. The NIFE vehicle's design provided accommodation for the most advanced Global Positioning System (GPS) - based means of position and attitude determination possible, as part of its guidance, navigation, and control (GN&C) system. Both service vehicle providers, Alpha and Beta, had independently resolved to use relative-GPS, in an oversimplified sense the differencing between a service vehicle's GPS data and that of the NIFE, as a means of navigating to within sneezing range of NIFE. To have any hope of meeting their respective accuracy requirements, Alpha and Beta would need sophisticated GPS transceiver equipment and software capable of making complex transformations of the data being transmitted. Each incoming vehicle needed to communicate with NIFE, not only for relative-GPS purposes, but to exchange data regarding system health, status, moding, etc., upon which proceed/wave-off decisions would be made.

Enter the Porcupine…

In the Program's constraint-induced push to develop the NIFE and let other considerations take a back seat, the NIFE's GN&C and communications systems were designed solely to satisfy NIFE requirements. My team, faced with integrating Vehicle A, found that the navigation system being developed by Alpha to interface with the NIFE's systems required a totally different data transfer protocol than NIFE would supply. Its communications system was different enough to require the addition of separate antennae and other hardware on the NIFE side. The Vehicle A integration complexity and costs were extremely high as a result. To add insult to injury, there was a serious question of whether the NIFE navigation system, designed solely to allow NIFE to find its position in space, would even be accurate enough to support relative-GPS navigation by Vehicle A, or any other visitor. To our amazement, we found that the NIFE GN&C community had not even been involved with previous Vehicle A related negotiations, technical interchange meetings, etc.; another symptom of the "haven't got time for this" bug. No wonder a disconnect existed!

The story with Vehicle B was even worse. Beta, originally wanting their vehicle to come to the NASA-controlled upwind NIFE port, had been pushed "downwind" by politics, to a port controlled by one of our international partners. This port made use of yet another communication system and, because it relied on a non-GPS set of satellites for navigation, had no requirement to receive GPS data from the NASA end of NIFE. A completely new set of hardware, including antennae, transceiver equipment, etc., had to be designed from scratch for use here. Since the modules at this end of NIFE were among the very first to be placed into orbit, their designs were complete, and changes thereto would not only be expensive, but would require after-the-fact extravehicular activity on-orbit to implement. Vehicle B's relative navigation system design, having proceeded without the expertise resident on our team, was quickly determined to be poor enough to render the proposed system unusable. Shortly after our RPOC team came together and assumed its lead role, Beta lost a critical year of its schedule to the unsuccessful pursuit of reinstatement to NIFE's upwind port. The question of whether this vehicle, upon which a significant amount of future NIFE resupply traffic depended, would materialize in time (or at all) became a very real issue.

What to do? The NIFE, with a different set of navigation/communication equipment for each servicing vehicle to approach it, was beginning to look like a porcupine. The added integration complexity was only to be surpassed by the difficulty to be faced by crews training to use and maintain the myriad systems being developed. Costs for implementation were climbing rapidly, and the RPOC system designs on the table were marginal at best.

Continued...

Can't We All Just Get Along…?

Clearly, the Systems Engineering 101 solution would be for NIFE to have a single integrated system each for navigation, communications, and so forth, which it and each servicing vehicle would use in common. Was that still possible, given the late point in the design cycle? After several quick studies, my team determined that yes, the existing GPS system would suffice for accuracy in the early NIFE stages, and that the addition of a single antenna array atop a downstream, Alpha-supplied NIFE module, would work for the remainder of NIFE's on-orbit life. The NIFE's data transport infrastructure, with relatively minor changes, was sufficient to allow both docking ports to use the same GPS data. Beta was willing to incorporate the Alpha-developed transceiver hardware into Vehicle B's design, which would cut Beta's design cycle and provide a sale for Alpha. It looked to us like the downstream port could readily be modified to accept use of this new transceiver equipment as well. On paper, it seemed we had a winner! Technically, our commonality-based proposal was feasible, and the cost/schedule/risk trades definitely favored this option over the "separate ways" approach.

Then politics stepped in.

The partner in control of the downwind port had been counting on the revenue to be generated by sale to Beta of its yet-to-be-designed GPS-like transceiver system, as well as of its half of whatever design/redesign gyrations Beta could be maneuvered into. (Truth be told, since Vehicle B was eventually to supplement the existing resupply vehicle produced by the downwind port partner, that partner wasn't overly anxious for Beta to succeed anyway.) Alpha wasn't quite sure it wanted to add an array to its NIFE module, despite the design of that module being in its infancy, in order to preserve flexibility for some as-yet-undetermined future use of the real estate. And, of course, there was the NIFE Program's position: Providers of vehicles coming to NIFE were expected to change to conform to the NIFE design; any changes to NIFE infrastructure had to be paid for by the partner needing the change. (Put another way, even technical solutions an order of magnitude cheaper to implement would be discarded if NIFE had to bear the cost thereof.) The hurdles seemed to be multiplying rather than diminishing.

SysThink and SysSpeak

Our approach was to weave the technical facts into a politically desirable proposal, to be presented after the appropriate skids had been greased. We developed the data to show how the systems engineering approach would benefit the NIFE Program even if it paid for the requisite changes to the NIFE infrastructure. This included assessing the reduced risk of a less complex system (in development per schedule constraints and in long-term reliability), reduced crew training costs/on-orbit task times (and enhanced safety/productivity), and detailed integration impacts. We developed in-depth resource estimates, along with a plan for offsetting NIFE Program costs via barter arrangements with its affected partners.

The skid-greasing commenced via traditional and nontraditional routes: The traditional avenue involved briefing the NIFE Chief Engineer and other key individuals on the issues at hand, and securing their support for the Program discussions to follow. The nontraditional path was to organize the 1st AIAA NIFE Conference, with the inaugural theme being "Commonality: Common Problems, Common Solutions." Our Center Director and other officials key to the NIFE Program accepted our invitations to fill the keynote and other featured speaker slots. Alone the appearance of their names on the agenda implied high-level support of the commonality theme, and set the desired political tone for the conference. We seeded the program liberally with papers written by our group and colleagues, and the topics, heard by representatives from all the partners having a vested interest in our resident issue, were well received. Our international partners, in a typical display of pragmatism, embraced the commonality concept and presented several papers in support of the common solutions we had been working with them, and identified several additional opportunities for systems simplification. Since the conference drew audiences comprised primarily of NIFE Program-related personnel, the issues we had been working received wide advertisement, and the systems-engineering-approach solutions we were proposing benefited from thorough discussion in an open, non-threatening environment.

With this infusion of SysSpeak, the related seeds of SysThink began slowly to germinate throughout NIFE Program circles, as people began to understand that a systems engineering approach could not only solve the technical problems the RPOC area faced, but do so in the most cost- and schedule-effective manner. Pursuit of such solutions therefore began to be seen as a responsibility, not as an option, and securing programmatic approval of our team's proposals for common navigation and communication became a much easier task.

Epilogue

Our RPOC team's vision, to work technical solutions at a systems level which considers NIFE and its servicing vehicles to be one system, with commonality across subsystems as the optimal outcome, has proved to be a challenging one to implement, and our successes have been hard-won. This has been particularly true considering the inevitable politics of international ventures and the fact that, as is typical of late-in-the-design-cycle introduction of systems engineering practices, retrofitting commonality has been more expensive than designing it in to begin with would have been. But, as the saying goes, better late than never. Our team has already saved the NIFE Program, as well as partners Alpha and Beta, millions of dollars, not only through development and implementation of common system hardware, but through early identification of flaws in the servicing vehicles' designs and operational concepts. Moreover, our team's success in its approach has served to reaffirm the importance of systems engineering principles to other segments of the NIFE community. As an aside, Alpha, with its internal systems engineering emphasis on buildup of test/verification facility infrastructure, frequent early ground/flight testing, etc., continues to demonstrate successful budget, schedule, and technical performance, despite re-vectoring required by NASA's late attention to RPOC and systems engineering. Beta, having cut similar measures to keep within its optimistic proposal, is behind schedule, over budget, and has no viable RPOC system design to-date.

Perhaps we should all make it a priority to bury engineering and program office oldthink.

Continued...

Lessons-learned:

- All aspects of systems integration must be considered from the outset. There is no room for "we vs. they" or "today vs. (maybe) tomorrow" mentalities during budget-planning or -trimming exercises; minimum-but-adequate funding for all components and activities deemed necessary to achieve project success should be retained in whatever budget is carried forward for approval. If all critical line-items cannot be funded as required for success, then the project should not be undertaken. To low-ball the estimate to gain a project's approval demeans everyone associated with the practice, and is the surest path to failure and loss of credibility. A far more responsible path to a lower budget is the early employment of a sound systems engineering design approach, including such practices as the simplification of interfaces and the development of verifiable requirements.
- The initial systems related mistake often made is that of pushing the definition of a system to too low a level, thereby leaving the top-level integration to be solved later as a "tomorrow problem." In the above example, the NIFE top-level "system" should have encompassed not only the NIFE vehicle itself, but the vehicles intended to interact with it as well. This "largest common denominator" approach to systems definition should be the going-in position, not the after-the-fact one arrived at only after the "silo" approach runs into trouble.
- The infusion of SysSpeak and SysThink into a program office culture raises considerably the probability that the most efficient (and hence lowest risk/cost/schedule) engineering approach is pursued by the design team(s). Spreading this "gospel," so to speak, is the responsibility of every engineering project/program leader.